$$P_n = k\,TB \text{ Watts}$$

Where, k = Boltzmann's constant = 1.38×10^{-23} Joules/Kelvin.

B = Bandwidth of the noise spectrum (Hz).

T = Temperature of the conductor, °Kelvin

Above equation indicates that a conductor operated at a finite temperature can work as a generator of electrical energy. The thermal noise power P_n is proportional to the noise BW and conductor temperature.

5. High frequency or Transit time noise :

If the time taken by an electron to travel from the emitter to the collector of a transistor becomes comparable to the time period of the signal which is being amplified then the transit time effect will take place. This effect is observed at very high frequencies typically in the VHF range. Due to the transit time effect some of the carriers may diffuse back to the emitter. This gives rise to an input admittance, the conductance component of which increases with frequency. The very small currents induced in the input of the device by means of the random fluctuations in the output current will create random noise at high frequencies. Once this noise appears, it goes on increasing with frequency at a rate of 6 dB per octave.

Chapter 3 : Amplitude Modulation & Demodulation [Total Marks : 24]

Q. 1(a) Modulation index for AM should be less than one. Justify / contradict. **(4 Marks)**

Ans. :

Dec. 2014

Chapter 1 : Basics of Communication System [Total Marks : 02]

Q. 1(c) Define signal to noise ratio. **(2 Marks)**

Ans. :

Definition of Signal to Noise (S/N) ratio :

The quantitative way to measure the effect of noise is to use the signal to noise ratio (SNR) as a system parameter. SNR at the receiver input is defined as,

$$SNR_i = \frac{\text{Average input signal power}}{\text{Average input noise power}}$$

SNR is expressed in decibels (dB). Higher the value (S/N) better is the noise performance of the receiver. The SNR and B are exchangable. If for a given rate of information transmission, we need a bandwidth of B_1 and signal to noise ratio of SNR_1, then we can achieve the same transmission rate over a channel of bandwidth B_2 and signal to noise ratio SNR_2 where,

$$SNR_2 = (SNR_1)^{B_1/B_2}$$

For example if $B_2 = 2B_1$ then

$$SNR_2 = (SNR_1)^{B_1/2B_1} = (SNR_1)^{1/2}$$

$$\therefore \quad SNR_2 = \sqrt{SNR_1}$$

Thus if we double the bandwidth the required SNR reduces to the square root of earlier SNR. But in practice it is not possible to increase bandwidth unlimitedly.

Q. 1(a) Modulation index for AM should be less than one. Justify / contradict. **(4 Marks)**

Ans. :

If the modulation index of an AM wave is less than 1 then it is called as linear AM modulation. The envelope of AM wave is then the exact replica of the modulating signal and no waveform distortion is introduced. However if m is greater than 1, then over-modulation takes place and the envelope of AM wave gets distorted. Since all the information is contained in the shape of the envelope, some information is lost due to distortion. To avoid this m should be less than 1.

Q. 2 (a) Explain low level and high level modulation techniques with the help of diagram. **(10 Marks)**

Ans. : Low level modulation technique :

A simple low level modulator circuit using OP-AMP and FET is as shown in Fig. 2.

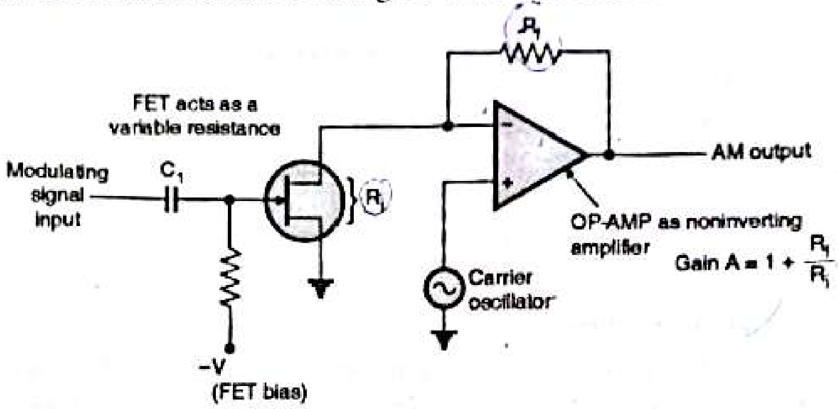


Fig. 2 : Low level modulator

Operation :

The OP-AMP is connected as a non-inverting amplifier for the carrier signal. The gain of this amplifier is $A = 1 + \frac{R_f}{R_i}$.

The feedback resistor R_f is of fixed value but R_i is the resistance offered by the N channel JFET. This resistance R_i is therefore variable.

A negative dc bias keeps the gate source junction of the JFET reverse biased. A modulating signal is applied to the gate through the coupling capacitor C_1. The resistance of JFET i.e. R_i will change in accordance with the modulating signal amplitude. This will change the gain of the amplifier in accordance with the modulating signal.

Therefore the carrier signal applied at the non-inverting terminal will get amplified more for the positive going modulating signal. Gain will increase as R_i decreases when modulating signal is positive. On the other hand less amplification is provided to the carrier for negative going modulating signal. Thus the AM wave is produced at the output of the OP-AMP amplifier.

High level modulation technique :

The property of tuned circuit states that if we apply a current pulse to a tuned circuit then it generates damped voltage oscillations at its output. The amplitude of oscillations is proportional to the size of current pulse and the decay rate is proportional to the time constant. This is called as the flywheel effect in a tuned circuit.

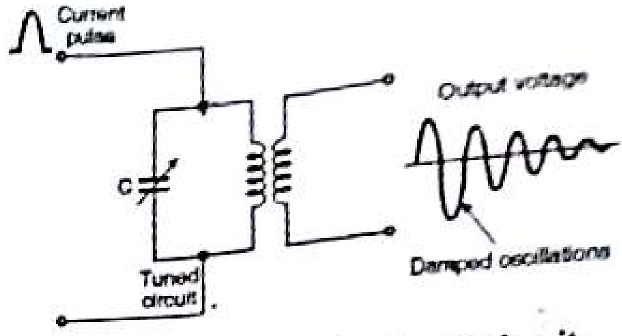


Fig. 3 : The property of tuned circuit

Requirements of a high level modulator :

Keeping in mind the property of the tuned circuit the essential parts of a high level modulation system are :

1. A tuned circuit and
2. A circuit supplies current pulses to the tuned circuit. If the amplitude of current pulses is made proportional to the amplitude modulating signal then AM wave will be generated at the output of tuned circuit.

(10 Marks)

... detector with delayed AGC in detail.

Chapter 2 : Noise [Total Marks : 12]

Q. 1(c) Define noise figure. **(2 Marks)**

Ans. : Definition of noise figure :

Sometimes the noise factor is expressed in decibels. When noise factor is expressed in decibels it is called noise figure.

$$\text{Noise figure} = F_{dB} = 10 \log_{10} F$$

Substituting the expression for the noise factor we get

$$\text{Noise figure} = 10 \log_{10} \left[\frac{\text{S/N at the input}}{\text{S/N at the output}} \right]$$

$$\therefore \quad F_{dB} = 10 \log_{10} (S / N)_i - 10 \log_{10} (S / N)_o$$

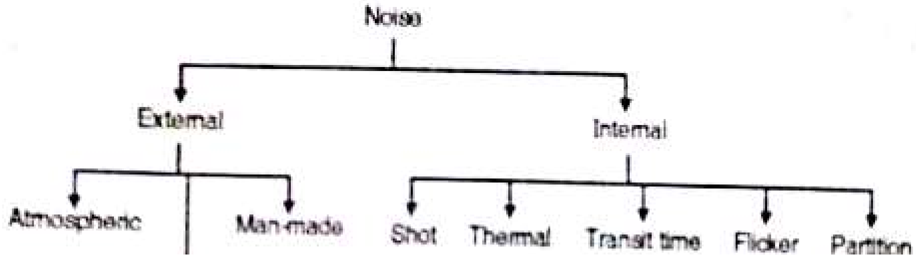
$$\therefore \quad \text{Noise figure } F_{dB} = (S / N)_i \text{ dB} - (S / N)_o \text{ dB}$$

The ideal value of noise figure is 0 dB.

Q. 6(b) Classify and explain different types of noise affecting communication. **(10 Marks)**

Ans. : Types of noises :

The classification of noise sources is shown in Fig. 1.



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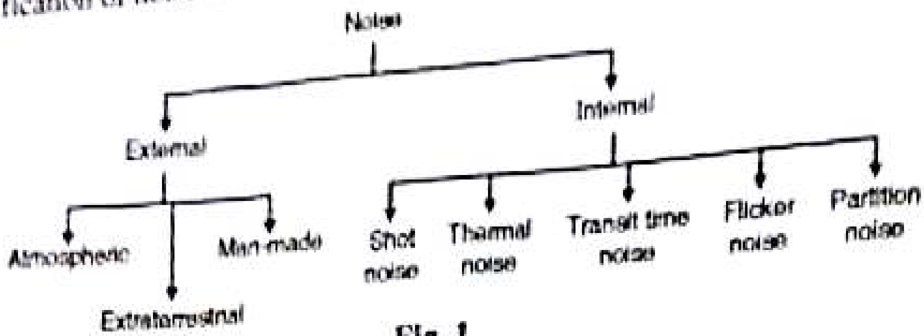


Fig. 1

External noises :

It is defined as the noise that is generated outside the device or circuit. As shown in Fig. 1, the external noise can be of three types :

1. **Atmospheric noise :**

   This type of noise gets produced within the Earth's atmosphere. The common source of this type of noise is lightning. This type of noise is in the form of impulses or spikes which covers a wide frequency band typically upto 30 MHz. The sputtering, cracking etc heard from the loud speakers of radio is due to atmospheric noise. This type of noise becomes insignificant above 30 MHz.

2. **Extraterrestrial noise :**

   This type of noise originates from the sources which exist outside the Earth's atmosphere. Hence this noise is also called as deep space noise. The noise originating from the sun and the outer space is known as Extraterrestrial Noise. The extraterrestrial noise can be sub-divided into two groups : (a) Solar noise (b) Cosmic noise. Our sun being a large body at very high temperatures radiates a lot of noise. The noise radiation from sun varies with the temperature changes on its surface. The temperature changes follow a cycle of 11 years hence the cycle of great electrical disturbances (noise) also repeats after every 11 years. The cosmic noise comes from the stars. This is identical to the noise radiated by sun because stars also are large hot bodies. This noise is called as black body noise or thermal noise and it is distributed uniformly over the entire sky.

The noise also gets originated from the center of our galaxy, other galaxies and special type of stars such as "Quasars" and "Pulsars".

3. Man made noise (Industrial noise) :

The man made noise is generated due to the make and break process in a current carrying circuit. The examples are the electrical motors, welding machines, ignition system of the automobiles, thyristorised high current circuits, fluorescent lights, switching gears etc. This type of noise is also called as industrial noise.

Internal noises :

1. Shot noise :

The shot noise is produced due to shot effect. Due to the shot effect, shot noise is produced in all the amplifying devices or for that matter in all the active devices. The shot noise is produced due to the random variations in the arrival of electrons (or holes) at the output electrode of an amplifying device. Therefore it appears as a randomly varying noise current superimposed on the output. The shot noise "sounds" like a shower of lead shots falling on a metal sheet if amplified and passed through a loud speaker. The shot noise has a uniform spectral density like thermal noise. The exact formula for the shot noise can be obtained only for diodes. For all other devices an approximate equation is stated. The mean square shot noise current for a diode is given as

$$\overline{I_n^2} = 2\,(I + 2I_o)\,qB \text{ Amperes}^2$$

Where, I = Direct current across the junction (in Amp)

I_o = Reverse saturation current (in Amp)

q = Electron charge = 1.6×10^{-19} C.

B = Effective noise bandwidth in Hz.

2. Partition noise :

Partition noise is generated when the current gets divided between two or more paths. It is generated due to the random fluctuations in the division. Therefore the partition noise in a transistor will be higher than that in a diode. The devices like gallium arsenide FET draw almost zero gate bias current, hence keeping the partition noise to its minimum value.

3. Low frequency or flicker noise :

The flicker noise will appear at frequencies below a few kilohertz. It is sometimes called as "1/f" noise. In the semiconductor devices, the flicker noise is generated due to the fluctuations in the carrier density (i.e. density of electrons and holes). These fluctuations in the carrier density will cause the fluctuations in the conductivity of the material. This will produce a fluctuating voltage drop when a direct current flows through a device. This fluctuating voltage is called as flicker noise voltage. The mean square value of flicker noise voltage is proportional to the square of direct current flowing through the device.

4. Thermal noise or Johnson noise :

The free electrons within a conductor are always in random motion. This random motion is due to the thermal energy received by them. The distribution of these free electrons within conductor at a given instant of time is not uniform. It is possible that an excess number of electrons may appear at one end or the other of the conductor. The average voltage resulting from this non-uniform distribution is zero but the average power is not zero. As this power has appeared as a result of the thermal energy, it is called as the "thermal noise power". The average thermal noise power is given by,

transmitter over a communication channel or medium.

The receiver will "Demodulate" the received modulated signal and get the original information signal back. Thus demodulation is exactly opposite to modulation. In the process of modulation, the carrier wave actually acts as a carrier which carries the information signal (modulating signal) from the transmitter to receiver.

Need of modulation :

The baseband transmission has many limitations which can be overcome using modulation. In the process of modulation, the baseband signal is "translated" i.e. shifted from low frequency side to high frequency side of the frequency spectrum. This frequency shift is proportional to the frequency of carrier.

Chapter 2 : Noise [Total Marks : 10]

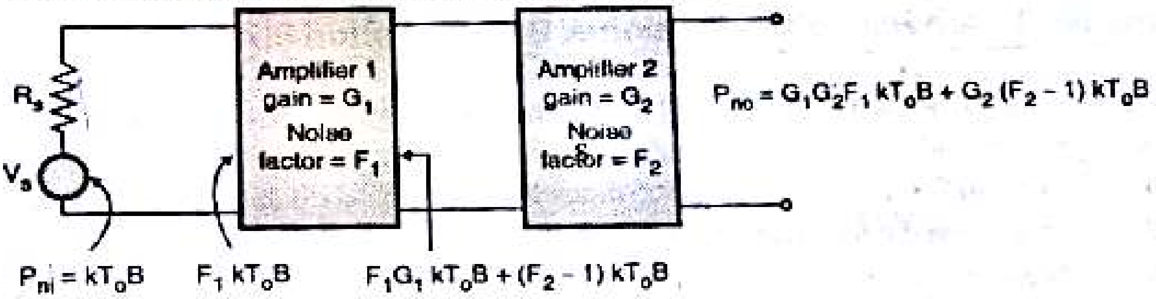
Q. 2(a) Derive Friiss formula for calculation of total noise figure, if two amplifiers are connected in cascade. **(10 Marks)**

Ans. :

Noise factor of amplifiers in cascade (Friiss formula) :

In practice the filters or amplifiers are not used in isolated manner. They are used in the cascaded manner. The overall noise factor of such cascade connection can be determined as follows :

Fig. Q. 2(a) shows two amplifiers connected in cascade.



(D-338) Fig. Q. 2(a) : Two amplifiers connected in cascade

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Let the power gains of the two amplifiers be G_1 and G_2 respectively and let their noise factors be F_1 and F_2 respectively.

The total noise power at the input of the first amplifier is given as :

$$P_{ni\,(total)} = F_1\, k\, T_o\, B \quad ...(1)$$

The total noise power at the output of amplifier 1 will be the addition of two terms.

$$\therefore \text{ Noise input to amplifier 2} = G_1\, F_1\, k\, T_o\, B + (F_2 - 1)\, k\, T_o\, B \quad ...(2)$$

The first term represents the amplified noise power (by G_1) and the second term represents the noise contributed by the second amplifier.

The noise power at the output of the second amplifier is G_2 times the input noise power to amplifier 2.

$$\therefore P_{no} = G_2 \times (\text{Noise input to amplifier 2})$$

$$\therefore P_{no} = G_1\, G_2\, F_1\, k\, T_o\, B + G_2\, (F_2 - 1)\, k\, T_o\, B \quad ...(3)$$

The overall gain of the cascade connection is given by,

$$G = G_1\, G_2 \quad ...(4)$$

The overall noise factor F is defined as follows :

$$F = \frac{P_{no}}{G_1\, G_2\, P_{ni}} \quad ...(5)$$

Here P_{ni} = Noise power supplied by the input source = $k\, T_o\, B$

Substituting the values of P_{no} and P_{ni} we get,

$$F = \frac{G_1\, G_2\, F_1\, k\, T_o\, B + G_2\, (F_2 - 1)\, k\, T_o\, B}{G_1\, G_2\, k\, T_o\, B}$$

$$\therefore F = F_1 + \frac{(F_2 - 1)}{G_1} \quad ...(6)$$

The same logic can be extended for more number of amplifiers connected in cascade. Then the expression for overall noise factor F would be,

$$F = F_1 + \frac{(F_2 - 1)}{G_1} + \frac{(F_3 - 1)}{G_1\, G_2} + \frac{(F_4 - 1)}{G_1\, G_2\, G_3} + \cdots \quad ...(7)$$

This formula is known as the **Friiss formula.**

onclusion :

This equation indicates that in the cascade configuration, the first stage is the most important ge in deciding the overall noise factor.

This is because due to presence of terms G_1, $G_1\, G_2$ ...... in the denominators of second, third terms ectively ......, they become negligibly small as compared to the first term.

$$\therefore F = F_1 \quad ...(8)$$

Chapter 3 : Amplitude Modulation & Demodulation [Total Marks : 15]

Chapter 1 : Basics of Communication System [Total Marks : 05]

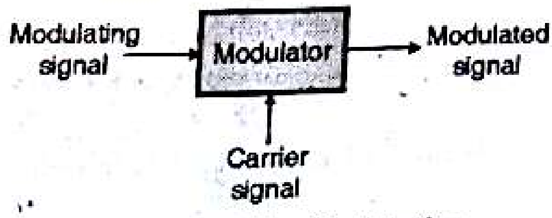
Q. 1(a) What is modulation ? Explain the need of modulation. **(5 Marks)**

Ans. :

Modulation :

In the Modulation process, two signals are used namely the modulating signal and the carrier. The modulating signal is nothing but the baseband signal or information signal while carrier is a high frequency sinusoidal signal.

In the modulation process some parameter of the carrier wave (such as amplitude, frequency or phase) is varied in proportion with the modulating signal. The result of this process is called as the modulated signal. This modulated signal is then transmitted by the transmitter over a communication channel or medium.



(D-8) **Fig. Q. 1(a) : Modulation**

The receiver will "Demodulate" the received modulated signal and get the original information signal back. Thus demodulation is exactly opposite to modulation. In the process of modulation, the carrier wave actually acts as a carrier which carries the information signal (modulating signal) from the transmitter to receiver.

Need of modulation :

The baseband transmission has many limitations which can be overcome using modulation. In the process of modulation, the baseband signal is "translated" i.e. shifted from low frequency side to high frequency side of the frequency spectrum. This frequency shift is proportional to the frequency of carrier.

Chapter 2 : Noise [Total Marks : 10]

Q. 2(a) Derive Friiss formula for calculation of total noise figure, if two amplifiers are connected in cascade. **(10 Marks)**

Ans. :